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78-10179
CR-157274

RETRANSMISSION OF
HYDROMETRIC DATA
IN CANADA

(E78-10179) RETRANSMISSION OF HYDROMETRIC DATA IN CANADA Final Report, Jul. 1974 - Mar. 1978 (Department of the Environment, Ottawa) 34 p HC A03/MF A01	N78-32513
CSCI 08H	Unclas
G3/43	00179

SR 28190

FINAL REPORT

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SR 28190

FINAL REPORT

1. SR No. 28190	2. Type of Report Final	3. Recipient's Catalog No.
4. Title Retransmission of Hydrometric Data in Canada		5. Report Date April 1978
		6. Period Covered July 1974 - March 1978
7. Principal Investigator R.A. Halliday		8. No. of Pages 38
9. Name and Address of Principal Investigators Applied Hydrology Division Department of Fisheries and the Environment Ottawa, Ontario, Canada K1A 0E7		10. Principal Invest. Rept. #
		11. GSFC Technical Monitor Frederick Gordon
12. Sponsoring Agency Name and Address Canada Centre for Remote Sensing Department of Energy, Mines and Resources Ottawa, Ontario, Canada K1A 0Y7		13. Key Words (Selected by Principal Investigator) Landsat, Data Collection Platform, Water Resources Data, Ground Station
14. Supplementary Notes Report prepared by R.A. Halliday and I.A. Reid		
15. Abstract The network of 10 Data Collection Platforms used in the Landsat-1 program was successfully expanded to about 30 DCPs. Parameters transmitted include water level, water velocity, air temperature, precipitation, ice condition, DCP battery voltage and water stage recorder operation check. A receive station for the DCS data was installed at Prince Albert. Some problems were encountered with the DCPs and the receive station but these have been overcome. The near real-time data are used for water management purposes and for planning hydrometric field operations. Preliminary economic analysis of the system indicates that satellite telemetry is cost effective and that the network of DCPs could be significantly expanded.		

SR 28190 - RETRANSMISSION OF HYDROMETRIC DATA IN CANADA
TYPE III FINAL REPORT

I. INTRODUCTION

The Water Survey of Canada operates over 2400 gauging stations at which water level and other related data are collected. Because of the isolated locations of many of these stations, it usually is not economically feasible to telemeter data from the sites by conventional means. For this reason, an experiment was conducted which involved retransmitting data from nine sites using Landsat 1. The results of this successful experiment were documented in a previous report.*

In response to a demand for near real time data from additional sites it was decided to implement a network of about 30 sites on a quasi-operational basis. It was expected that this follow on program would approximate an operational situation thus making it possible to quantify some of the benefits of satellite data collection. As part of the program, it was decided to install additional equipment at the existing Prince Albert Satellite Station to enable direct reception of data.

This report covers the techniques used in conducting the follow on program and the achievements of the program.

II. TECHNIQUES

Site Selection

The sites at which Data Collection Platforms (DCPs) were installed were selected by Water Survey of Canada District Offices on the basis of demand for real-time data and lack of conventional

*SR 9629 - Water Survey of Canada: Use of ERTS-1 for Retransmission of Water Resources Data, Type III Report dated August, 1974

means of providing such data. In some cases such as flood forecasting or flow forecasting for navigation, the requirement for real-time data was seasonal; in others, it was year-round. The locations of the sites are illustrated in Figure 1 and listed in Table 1. Some typical examples of data uses are as follows:

a) Six DCPs were used in the Mackenzie River basin to provide data for the preparation of daily water level forecasts during the short navigation season. The river is the main means of transporting bulk cargo for re-supply of settlements and for oil companies in the western Arctic.

b) One DCP was installed on Battle Creek at the International Boundary (an international gauging station). Access to this site is difficult, especially in poor weather. Data are used during the irrigation season in computing the 10 day apportionment of flow between Canada and the United States.

c) One DCP was installed on the Severn River in southern Ontario. This gauging station on the Trent-Severn Waterway, a major recreational waterway, is below the confluence of several small streams, all of which are regulated. The river is also regulated downstream from the DCP site. Water level and water velocity data are used to compute river discharge. Water temperature data are also transmitted to assist in winter flow computations.

d) Three DCPs were installed in the Ottawa River basin and one on the Saint John River to provide data for input into Streamflow Synthesis and Reservoir Regulation

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FIGURE 1

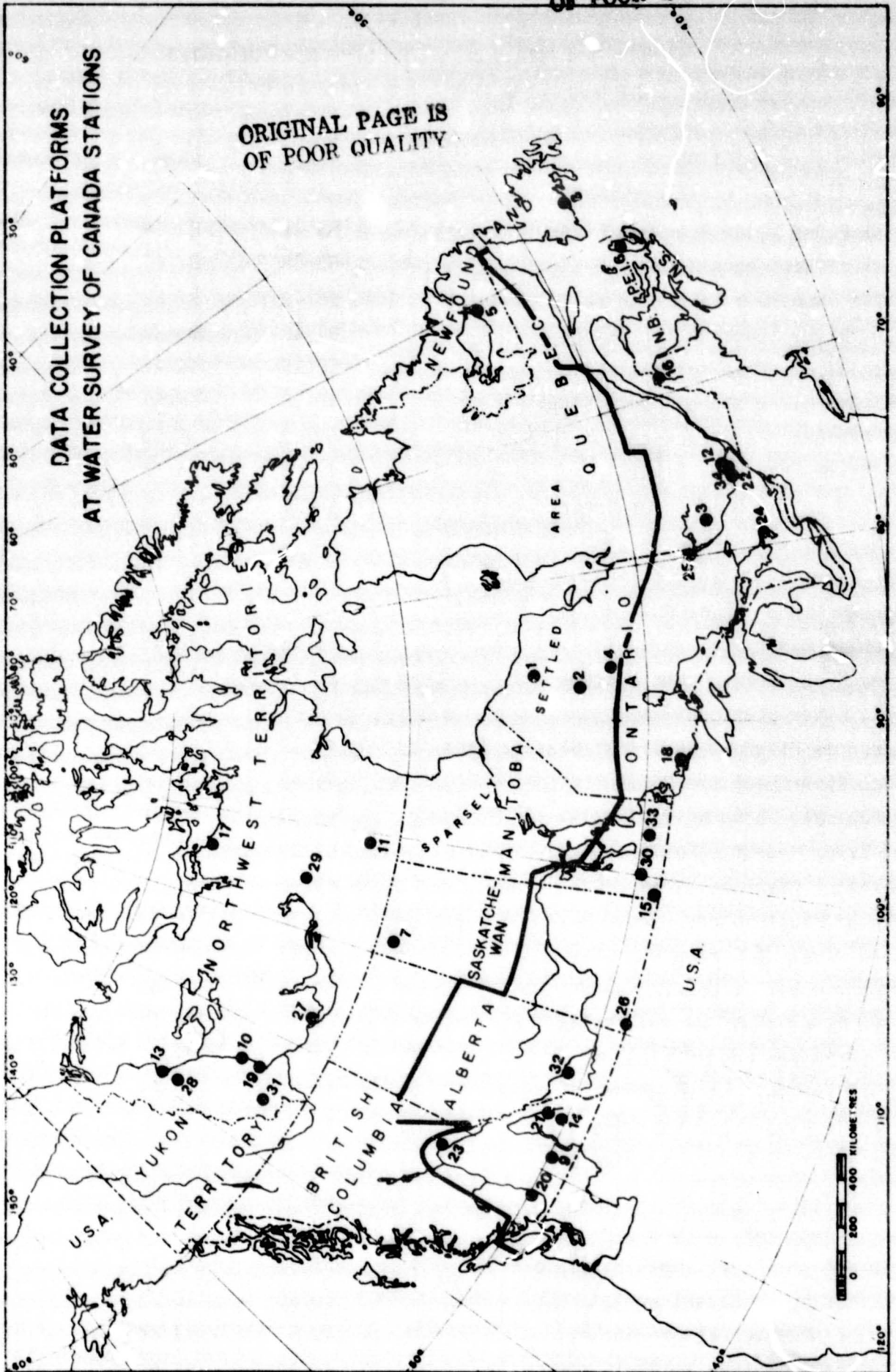


TABLE 1
HYDROMETRIC STATIONS WHERE DCPs WERE DEPLOYED
AT SOME TIME FROM JULY, 1974 TO DATE

STATION	LAT.	LONG.	COMMENTS
1 Winisk River below Asheweig River Tributary	54 31	87 14	
2 Winisk at Kanuchuan Rapids	52 58	87 42	
3 Rivière Dumoine a la Sortie du Lac Dumoine	46 49	77 52	RNQ Station
4 Albany River above Nottik Island	51 38	86 24	
5 Churchill River at Muskrat Falls	53 15	60 47	
6 Cheticamp River above Robert Brook	46 38	60 57	
7 Lake Athabasca at Crackingstone Point	59 23	108 53	
8 Grey River near Grey River	47 45	56 56	
9 Snow course No. 5A Mission Creek	49 47	118 55	
10 Mackenzie River near Wrigley	63 16	123 36	
11 Kazan River at Outlet of Ennadai Lake	61 16	100 58	
12 Rouge en amont de La Chute McNeil	45 44	74 41	RNQ Station
13 Mackenzie River at Sans Sault Rapids	65 46	128 45	
14 Carney Creek below Pambrum Creek	50 10	116 35	
15 Souris River near Coulter	49 05	100 57	
16 St-Francis River at Outlet of Glasier Lake	47 12	68 57	GOES
17 Ellice River near the Mouth	67 42	104 08	
18 Namakan Lake above Kettle Falls	48 30	92 38	
19 Root River near the Mouth	62 29	123 26	
20 Nahatlatch River below Tachewana Creek	49 57	121 52	
21 Ridge of Mount Rhondda above Peyto Glacier	51 38	116 33	
22 Rideau River at Ottawa	45 23	75 42	Test Site
23 McGregor River at Lower Canyon	54 16	121 40	
24 Severn River above Wassell Falls	44 46	79 18	
25 Blanche River above Englehart	47 53	79 53	GOES
26 Battle Creek at International Boundary	49 00	109 25	
27 Mackenzie River near Fort Providence	61 15	117 30	
28 Mountain River below Cambrian Creek	65 14	128 34	
29 Hanbury River above Hoare Lake	63 36	109 09	
30 Assiniboine River at Brandon	49 51	99 56	
31 South Nahanni River above Virginia Falls	61 38	125 48	
32 Bow River below Carseland Dam	50 50	113 25	Test Site
33 Assiniboine River at Headingley	49 52	97 24	GOES
34 De La Petite Nation au Pont a 1.0 mi en amont de Ripon	45 48	75 05	ANIK, RNQ

(SSARR) models of the watersheds. Some of the DCPs in the Ottawa River basin were installed at gauging stations operated by the Ministère des Richesses naturelles of the province of Québec (RNQ).

e) One DCP was installed on the Grey River in Newfoundland to monitor an anadromous fisheries agreement between Newfoundland Hydro and the Department of Fisheries. The purpose of the agreement is to maintain a minimum flow in the river at all times.

Equipment

During the follow on program a total of 29 DCPs were operated in the Landsat mode at Water Survey of Canada gauging stations. These include the original 9 General Electric DCPs purchased in 1971 and delivered in 1972 plus another General Electric DCP that was shared with the Glaciology Division. (Reports on the use of this DCP during the initial program were submitted to NASA by Dr. Jaan Kruus.) An additional 19 DCPs, one of which was equipped with a 720 bit memory, were purchased from Ball Brothers Research Corporation and delivered in 1975. These DCPs are convertible between Landsat and GOES. Apparent gaps in the Landsat record for a DCP can often be attributed to that platform being operated in the GOES mode. One significant improvement in the Ball DCPs was that Company's use of a 350 mm square micro-strip antenna. The 1050 mm diameter ground plane supplied with the GE DCPs had presented some problems in deploying DCPs. Another advantage of the Ball DCPs was that the DCPs were in sealed containers, however humidity had not really been a problem with the GE DCPs deployed in Canada. In 1977 three DCPs were purchased from LaBarge Electronics - these will be installed in 1978.

During the follow on program one GOES DCP manufactured by Bristol Aerospace and one Comsat General DCP manufactured by Magnavox were also operated. The purpose of operating the Bristol DCP was to evaluate a Canadian manufacturer's product while that of operating the Comsat General DCP was to obtain an appreciation for the use of commercial communications satellites for data telemetry.

The sensors used with the DCPs are summarized in Table 2. Most of these sensors were used in the initial project, the only additions being an Atlas Flora 10 ultrasonic flow meter and a YSI Series 400 thermistor for measuring temperatures of water as well as air. Only one site was equipped with an ultrasonic flow meter. These instruments measure water velocity on a line between two transducers and the results are used, along with water level data, to produce total flow figures.

The most widely used power source for both DCPs and sensors (where required) was a heavy duty 12 V car battery although rechargeable alkaline and nickel-cadmium batteries were also used. In one case Cipel & LeCarbonne air depolarized cells were installed. The latter cells are not rechargeable and therefore their attractiveness as a power source has been reduced by the wide availability of small, low cost solar panels.

Where necessary, equipment was heated using Cata-Dyne BX 3x4 catalytic propane heaters having an adjustable 200 to 700 kJ/hr output.

Data Handling and Processing

The data transmitted by DCPs are processed by NASA then sent to Canada in two ways. The first is by land line to the Canada Centre for Remote Sensing (CCRS) in Ottawa. The data

TABLE 2 - SENSORS USED WITH WATER SURVEY OF CANADA LANDSAT DCPs

PARAMETER	SENSOR	INSTRUMENT	INTERFACE
WATER LEVEL	FLOAT	STEVENS MEMOMARK II	CONTAINED IN MEMOMARK
	PRESSURE	CAE SERVOMANOMETER	STEVENS MEMOMARK II
WATER VELOCITY	ELECTROMAGNETIC	MARSH-HICEIMNEY	ANALOGUE INTEGRATOR
	ACOUSTIC	ATLAS FLORA 10	NONE REQUIRED
ICE CONDITION	ELECTRO-MECHANICAL	NOT APPLICABLE	NONE REQUIRED
RECORDER OPERATION	ELECTRO-MECHANICAL	NOT APPLICABLE	NONE REQUIRED
PRECIPITATION	WEIGHING TYPE	FISCHER & PORTER	HARTS UNIT
AIR TEMPERATURE	PLATINUM RESISTANCE BULB		HARTS UNIT
	THERMISTER	YSI 401	
WATER TEMPERATURE	THERMISTER	YSI 410	
SNOW WATER CONTENT	SNOW PILLON	PRESSURE TRANSDUCER (BALL EX 410)	NONE REQUIRED
DCP BATTERY VOLTAGE	ELECTRONIC	NOT APPLICABLE	NONE REQUIRED

usually arrive shortly after each orbit of the spacecraft. At CCRS the data are recorded simultaneously on a teletype hard copier and on magnetic tape. A software data retrieval system sorts the user platforms, reformats the data into engineering units and stores individual user files on disk. The user may then access the data file, usually daily, using either a Teletype (110 or 300 baud) or Telex remote terminal.

The second is by punch card and uncalibrated computer listings which arrive about two weeks after transmittal by the DCP. These data are delivered to the Canadian Embassy in Washington, D.C., then carried by diplomatic bag to the Department of External Affairs in Ottawa. External Affairs then mails the data to users.

The data received on a near real-time basis are usually discarded a short time after use but the data received in card form are retained for archival purposes and to develop statistics on DCP performance. These data are stored on magnetic tape in card-image format, so that historical data may be recovered and retrieved selectively by platform, date and time. Prior to being written to tape, the punched cards on which the data are received are read by a computer program which checks the card contents for validity and rejects invalid cards.

Three computer programs were written to process these data, either data on punched cards, or historical data retrieved from magnetic tape: (a) a program which decodes each transmission and prints out the values of the readings in engineering units; (b) a program which summarizes for each platform and each cycle of satellite orbits the daily mean number of transmissions and the number of days on which transmissions were received; (c) a program which summarizes for each platform and each cycle the total number of transmissions and the number of orbits during which

which transmissions were received. Typical products from these programs are shown in Figures 2 to 4.

In addition to the data handling procedures described above, a contract was awarded on August 16, 1976 to SED Systems Ltd for the development and installation of a Landsat/GOES (channel 13) receive facility at the Prince Albert Satellite Station (PASS). The principal activity at PASS is the tracking of Landsat and NOAA satellites in order to obtain imagery.

There were two objectives in installing data collection system capability at PASS. The first was to develop first hand experience in Canada in operating a data reception and distribution facility. There have been proposals for Canadian satellites that could be used in collection of environmental data and it was felt that first hand knowledge would be invaluable.

The second objective was to provide a means of making real-time data already converted to engineering units available to users of small numbers of DCPs on a 24 hour basis. The data would be available on a dial-up basis using Telex or 110 baud or 300 baud Teletype terminals. Capacity for eventual use of 1200 baud terminals would also be installed.

As checks of the retransmitted data that were conducted during the Landsat-1 project indicated that data flagged as valid were indeed valid, data verification during the follow on project consisted only of cursory checks to ensure that initial settings of sensors were correct.

III. ACCOMPLISHMENTS

During the reporting period, a maximum of 22 of the 29

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Figure 2

COMPANY OF REGISTERED DATA VIA ANSA-2 SATELLITE

MISSISSIPPI CREEK SITE

STATICA AC.

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PAGE 11

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DATE	TIME (EST)	ACCUMULATED PRECIPITATION	STAGE	AIR TEMP. (CELSIUS)	66 VOLTS	SACK FILLON (IN.)	66 VOLTS
10/10/73	14:00	5.5	22.00	-	0.00	15.25	4.500
10/10/73	14:05	5.5	22.00	-	0.00	15.25	4.500
10/10/73	14:10	5.5	22.00	-	0.00	17.12	4.500
10/10/73	14:15	5.5	22.00	-	0.00	15.25	4.500
10/10/73	14:20	5.5	22.00	-	0.00	15.14	4.500
10/10/73	14:25	5.5	22.00	-	0.00	15.14	4.500
10/10/73	14:30	5.5	22.00	-	0.00	15.14	4.500
10/10/73	14:35	5.5	22.00	-	0.00	15.14	4.500
10/10/73	14:40	5.5	22.00	-	0.00	15.14	4.500
10/10/73	14:45	5.5	22.00	-	0.00	15.14	4.500
10/10/73	14:50	5.5	22.00	-	0.00	15.14	4.500
10/10/73	14:55	5.5	22.00	-	0.00	15.14	4.500
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10/10/73	24:00	5.5	22.00	-	0.00	15.14	4.500
10/10/73	24:05	5.5	22.00	-	0.00	15.14	4.500
10/10/73	24:10	5.5	22.00	-	0.00	15.14	4.500
10/10/73	24:15	5.5	22.00	-	0.00	15.14	4.500
10/10/73	24:20	5.5	22.00	-	0.00	15.14	4.500
10/10/73	24:25	5.5	22.00	-	0.00	15.14	4.500
10/10/73	24:30	5.5	22.00	-	0.00	15.14	4.500
10/10/73	24:35	5.5	22.00	-	0.00	15.14	4.500
10/10/73	24:40	5.5	22.00	-	0.00	15.14	4.500
10/10/73	24:45	5.5	22.00	-	0.00	15.14	4.500
10/10/73	24:50	5.5	22.00	-	0.00	15.14	4.500
10/10/73	24:55	5.5	22.00	-	0.00	15.14	4.500
10/10/73	25:00	5.5	22.00	-	0.00	15.14	4.500
10/10/73	25:05	5.5	22.00	-	0.00	15.14	4.500
10/10/73	25:10	5.5	22.00	-	0.00	15.14	4.500
10/10/73	25:15	5.5	22.00	-	0.00	15.14	4.500
10/10/73	25:20	5.5	22.00	-	0.00	15.14	4.500
10/10/73	25:25	5.5	22.00	-	0.00	15.14	4.500
10/10/73	25:30	5.5	22.00	-	0.00	15.14	4.500
10/10/73	25:35	5.5	22.00	-	0.00	15.14	4.500
10/10/73	25:40	5.5	22.00	-	0.00	15.14	4.500
10/10/73	25:45	5.5	22.00	-	0.00	15.14	4.500
10/10/73	25:50	5.5	22.00	-	0.00	15.14	4.500
10/10/73	25:55	5.5	22.00	-	0.00	15.14	4.500
10/10/73	26:00	5.5	22.00	-	0.00	15.14	4.500
10/10/73	26:05	5.5	22.00	-	0.00	15.14	4.500
10/10/73	26:10	5.5	22.00	-	0.00	15.14	4.500
10/10/73	26:15	5.5	22.00	-	0.00	15.14	4.500
10/10/73	26:20	5.5	22.00	-	0.00	15.14	4.500
10/10/73	26:25	5.5	22.00	-	0.00	15.14	4.500
10/10/73	26:30	5.5	22.00	-	0.00	15.14	4.500
10/10/73	26:35	5.5	22.00	-	0.00	15.14	4.500
10/10/73	26:40	5.5	22.00	-	0.00	15.14	4.500
10/10/73	26:45	5.5	22.00	-	0.00	15.14	4.500
10/10/73	26:50	5.5	22.00	-	0.00	15.14	4.500
10/10/73	26:55	5.5	22.00	-</			

Figure 3

SUMMARY OF RETRANSMITTED DATA FOR 1976													
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PLATFORM F.O.	29 JUL 3 TO JUL 20	30 JUL 21 TO AUG 7	31 AUG 8 TO AUG 25	32 AUG 26 TO SEP 12	33 SEP 13 TO SEP 30	34 OCT 1 TO OCT 18	35 OCT 19 TO NOV 5	-----DAILY-----					
								MAX.				MIN.	CYCLE TOTALS
4102	9 (18)	8 (18)	8 (18)	8 (18)	8 (18)	---	---	11 ON JUL 18	4 ON AUG 3				712
4126	5 (18)	5 (18)	5 (18)	5 (18)	5 (18)	---	---	9 ON JUL 15	1 ON AUG 20				467
4137	21 (18)	20 (18)	19 (18)	18 (18)	18 (18)	---	---	24 ON JUL 4	13 ON AUG 26				1725
4150	30 (18)	30 (18)	29 (18)	27 (18)	29 (18)	---	---	34 ON JUL 18	19 ON AUG 27				2605
4210	11 (16)	14 (18)	10 (4)	5 (18)	5 (17)	---	---	19 ON JUL 30	1 ON SEP 29				651
4232	12 (18)	13 (18)	12 (18)	12 (18)	12 (18)	---	---	19 ON AUG 22	8 ON AUG 6				1106
4260	50 (12)	50 (18)	47 (18)	43 (18)	44 (18)	---	---	58 ON JUL 31	21 ON AUG 26				3906
4353	28 (16)	---	1 (1)	---	31 (11)	---	---	45 ON JUL 17	1 ON JUL 18				793
4354	1 (14)	7 (12)	5 (17)	5 (18)	9 (18)	---	---	13 ON JUL 31	1 ON JUL 3				434
4366	31 (18)	31 (18)	28 (18)	27 (18)	29 (18)	---	---	37 ON JUL 20	6 ON AUG 26				2612
4501	---	1 (4)	1 (8)	5 (6)	13 (2)	---	---	17 ON SEP 13	1 ON AUG 4				68
4502	11 (18)	11 (18)	11 (18)	10 (17)	10 (18)	---	---	15 ON AUG 7	7 ON AUG 25				951
4504	10 (18)	10 (18)	10 (18)	10 (17)	10 (18)	---	---	15 ON AUG 8	4 ON SEP 2				896
4507	14 (18)	15 (18)	15 (18)	13 (17)	19 (18)	---	---	25 ON SEP 21	7 ON AUG 25				1327
4512	14 (18)	17 (18)	14 (18)	12 (18)	14 (18)	---	---	20 ON JUL 31	2 ON AUG 26				1313
4514	9 (18)	8 (18)	6 (18)	8 (18)	9 (18)	---	---	13 ON AUG 1	1 ON AUG 14				722
4522	---	6 (8)	6 (4)	---	---	---	---	10 ON AUG 1	2 ON JUL 29				71
4524	---	---	---	---	10 (16)	---	---	13 ON SEP 17	6 ON SEP 15				154

Figure 4

TRANSMISSIONS FROM LANDSAT-2 SATELLITE
DURING CYCLE 028 (JUN 14 1976 THRU JUL 01 1976)

PLATFORM A150 159 23 N 108 53 W

JUL 21 1976

RECEIVE STATIONS	A	G	N	TOTAL
TRANSMISSIONS	319	129	122	570
OMITS	134	059	058	251
DUPLICATE TRANSMISSIONS				071
DUPLICATE OMITS				087
NO. OF OMITS (INCLUDING DUPLICATES)				164
NO. OF TRANSMISSIONS (INCLUDING DUPLICATES)				499

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DCPs were on the air in the Landsat mode at the same time. (Others could have been operating in the GOES mode.) In some cases DCPs operated at the same location for the entire period; in others, DCPs were operated for only a few months to meet short term data needs or to serve as a demonstration.

Prior to implementation of the Alaska receive site in December 1975, data were received on as many as seven orbits each day with as many as 20 messages being received each day. Since the Alaska down-link was installed some northern DCPs have averaged nearly 10 orbits for which data were relayed and, in addition, over 30 messages a day are received. In virtually all cases, it would be impossible to obtain data from the selected sites by conventional means at reasonable cost.

As in the Landsat-1 program, the DCPs proved to be reliable and accurate. Water level and several other parameters are transmitted and the data are used in near real-time on a quasi-operational basis.

At the end of 1977, the Landsat data collection system receive facility at Prince Albert Satellite Station began its operations. The receive equipment makes use of the same 26 m reflector that has been used since 1972 to receive Landsat imagery. In 1977 a 5.5 m antenna was installed as a back-up. A Data General Nova minicomputer having 32 K of memory is used to process the data. Basic operating criteria are as follows:

- a) The best Landsat message per DCP per hour is stored, or as a user option, all Landsat messages are stored. (All GOES messages are stored)
- b) Data are available in engineering units or, as a user

option, as unconverted data, by dial-up 110 and 300 baud Teletype lines or by Telex.

c) Statistics on DCP operation are available.

Typical data products are shown in Figure 5.

Problems were encountered in making the system operational. These will be discussed later in this report.

IV. SIGNIFICANT RESULTS

The Landsat program has demonstrated that polar orbiting satellites can be used to relay hydrologic data from any part of Canada to a user without difficulty and at low cost. These data can be used for many operational purposes, the most important of which have been identified as follows: hydroelectric power plant operation; water supply for municipalities, industries and irrigation; navigation; flood forecasting; operation of flood control structures and systems; and recreation.

In many cases, the benefits of real time data are difficult to quantify. However, a recent economic evaluation of hydrometric data (Acres, 1977) indicated a benefit cost ratio of 9.3 for hydrometric data collection in Canada. Both design benefits, which only require archival data, and operating benefits, which require near real time data, were identified. Although design benefits are much larger than operational benefits, it is safe to say that the operational benefits alone are larger than the total cost of conducting the hydrometric data gathering program in Canada.

Unfortunately for the organizations that operate gauging

Figure 5 - Landsat Data from PASS

LOG WSCWPG

LOGGED ON AT:16: 5:13

LIST T 116/18

PLATFORM CEB/6353

MQ	DDDHMMSS	LEVEL	D3	D4	D5	D6	D7	D8
7	116204539	13.48	0.000	0.000	00	00	0.000	0.000
7	117014734	13.48	0.000	0.000	00	00	0.000	0.000
7	117032538	13.48	0.000	0.000	00	00	0.000	0.000
6	117154322	13.48	0.000	0.000	00	00	0.000	0.000

END OF MESSAGES

PLATFORM D79/6571

MQ	DDDHMMSS	LEVEL	D3	D4	D5	D6	D7	D8
7	117032111	08.04	1.210	2.421	00	00	2.968	0.468
7	117155015	07.98	1.132	2.421	00	00	2.949	0.468

END OF MESSAGES

LOG

LOGGED OFF AT:16: 7:50

PLEASE LOG ON

LOG WSCWPG

LOGGED ON AT:16: 8:11

LIST RAW P D79 T 116/18

PLATFORM D79/6571

MQ	DDDHMMSS	D1	D2	D3	D4	D5	D6	D7	D8
7	117032111	01	02	3E	7C	00	00	98	18
7	117155015	0E	91	3A	7C	00	00	97	18

END OF MESSAGES

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stations, the benefits discussed above accrue to organizations other than the operating entity and, in some cases to society as a whole. To evaluate the benefits of near real time data acquisition to a gauging station operator it is necessary to consider the costs of operating a network of gauging stations and the possible uses of real time data to the operator.

The average annual cost of collecting flow data continuously at a site in Canada was about \$5,000 in 1977 while the cost of collecting water level data was about \$2,000. (It is noteworthy that these figures are similar to those obtained in the United States (Moody and Preble, 1975)). About 60 percent of the Water Survey of Canada budget is used for salaries, 27 percent for operational expenses and 13 percent for capital acquisitions (including construction of gauging stations). Generally it is felt that widespread use of near real time data acquisition would have a neutral effect on salaries (but would permit more effective deployment of field staff), would tend to decrease operational costs, and would increase capital costs.

The average figures cited earlier do not really give a true picture of the possible savings in operational costs. There are a group of about 300 "remote access" gauging stations in Canada where operational costs are very high. The stations are serviced using fixed or rotary winged aircraft thus access costs are much higher than normal. Also, in these cases it is customary to use a two rather than one person field party. The cost of aircraft for this work depends on the zone where the aircraft is used, the far north being the most expensive. Typical aircraft costs are:

Twin Otter	\$425/hr
Jet Ranger	\$300/hr
Single Otter	\$200/hr

Charter companies specify a minimum daily charge-out rate of four hours in the summer and three in the winter. A visit to a site may take two to four hours depending on the gauging station and the work performed. Because of travel distances it is unlikely that more than two stations are visited on any one day; often, especially in the winter, only one station is visited. The cost of visiting one remote station could then range from, say, \$500 to \$2,000 for each trip. Five to ten trips are made each year.

There are several ways in which real time data acquisition can aid hydrometric field operations. These are:

a) Planning of field trips - If real time data indicates that all sensors at a site are operating normally and if flow conditions are such that a discharge measurement is not required, then a visit to the station can be omitted. On the other hand, if the real time data shows that it is desirable to obtain a measurement immediately, an extra trip can be scheduled. In at least one case in Canada, a DCP was used at a new remote gauging station to enable definition of an entire stage-discharge relation during a single spring freshet. Often, when trips are planned on a calendar basis, peak flows can be missed and it takes several high water periods to define a relation.

b) Planning of sensor maintenance - If real time data indicate a sensor malfunction, it is usually possible to diagnose the problem by examining the incoming data. (Many DCPs transmit battery voltage and recorder operation checks as well as sensor data. This also helps define a problem). A decision can then be made whether immediate repairs are warranted, or whether maintenance should be included on the next regularly scheduled trip into an area. In either case, the appropriate spare

parts can be carried in by the field crew thus completing the repair in one trip where otherwise two may be needed, (one to discover the problem, the second to do the repairs).

In the Canadian experience, DCPs are more reliable than some sensors so trips for DCP maintenance are seldom required. In any case DCP maintenance is performed by field substitution (after checking RF, cabling, batteries and fuses) and therefore is not a time consuming job. The RF monitors sold by GFA Engineering are used as a quick check of DCP performance.

c) Filling in missing record - Instances have occurred when field recorders have stopped but a sensor continues to function, for example water level and velocity recorders. In such cases the real time data can be used to fill in data that would otherwise be missing.

d) Primary collection of data - If the cost of acquiring real time data and the reliability of the system proved better than using in situ recorders, then satellite telemetry could be used as a primary means of data collection. This situation is not likely to arise in Canada, however the other benefits of real time data cited earlier plus the benefits of real time data to other organizations may make primary collection by satellite logical. Some work has been carried out to determine optimum sampling rates for accurate flow computations (Kite and Reid, 1976).

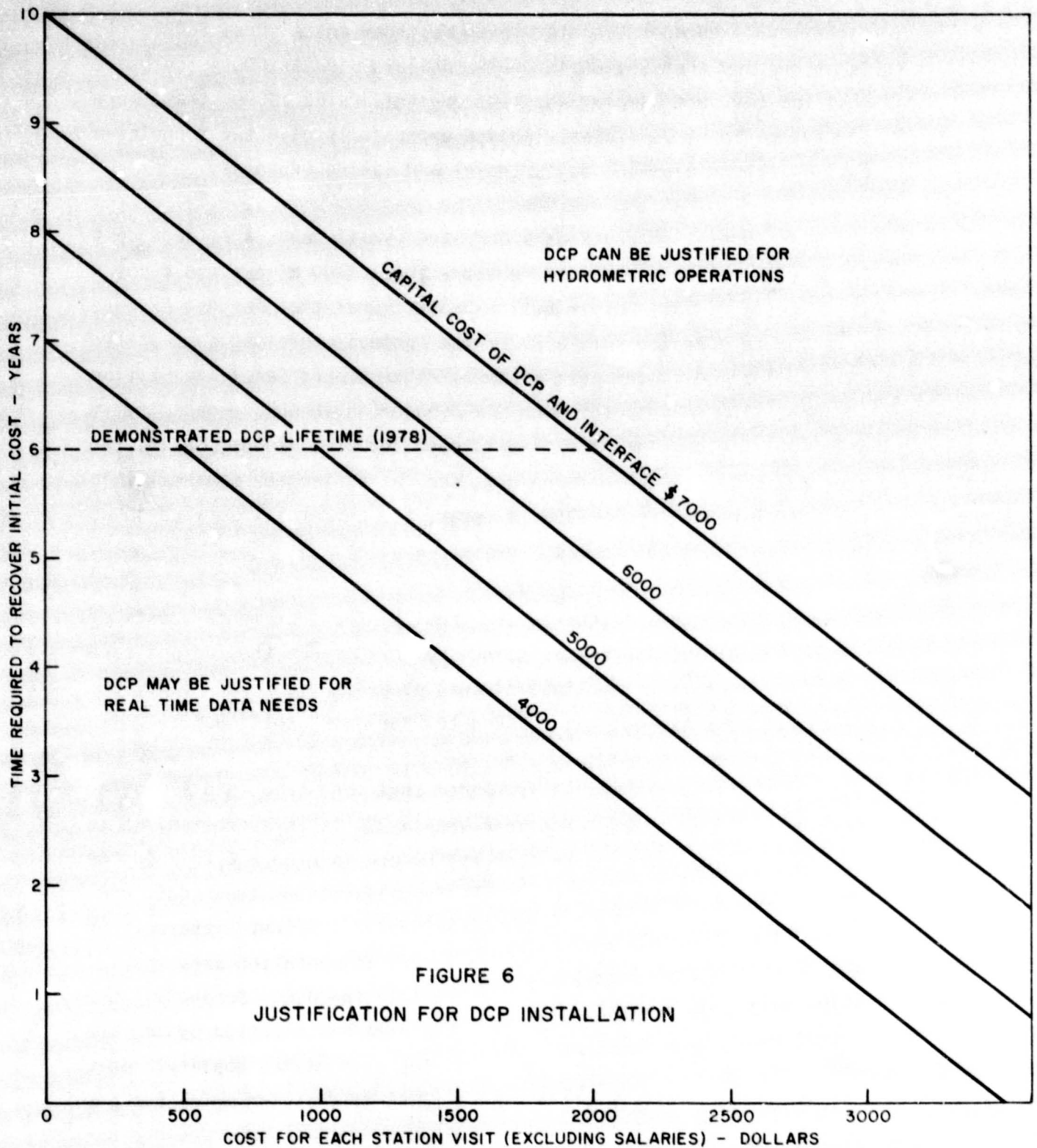
The current capital cost of satellite telemetry of water level data in Canada is about \$5,000 for a DCP plus \$1,000 for a

water level encoder (a water level recorder costs about \$800). It is noteworthy that \$5,000 in 1971 dollars is \$3,000 - the exact cost of the much simpler and less versatile GE DCPs that were purchased in 1971. Installation expenses involve two technician days of labour plus one day's travel and living expenses.

Operating costs of a DCP are small and are dependent largely on the frequency of repair - about \$100 a year would cover these costs. Data distribution costs are the largest expense relating to operation of DCPs. The annual operating cost of the data collection system part of the Prince Albert Satellite Station is about \$1000 a year for each DCP (based on 35 DCPs - capacity is over 100). Also since the site is operated on a dialup basis, the user must pay telephone charges for accessing the system. This cost could range from \$350 a year for commercial service to no direct cost when government lines are available.

The costs discussed are really the incremental costs of adding another DCP to the existing network since they do not take into consideration the initial cost at PASS which was \$160,000. Canadian users are not being asked to "pay back" this cost.

If the assumption is made that one trip into a gauging station could be saved each year when a DCP is in operation, it is possible to produce a graph such as the one in Figure 6 to show the justification required for a DCP installation. Two additional assumptions are made in producing the graph. First, there is no operational cost saving in the first year of operation as a special trip would have been made to install the DCP. Secondly, the operating cost of the DCP and the data distribution system are balanced by intangibles such as improved data quality, more effective use of field staff, and occasionally saving more than one trip a year.



For example, if a DCP and related interfacing can be purchased for \$6,000 and site access costs are \$1,500 for each trip, the DCP would start to pay for itself after 6 years of operation. Before that time it could be justified as a means of meeting real time data needs of an outside organization. The cut off point in determining when a DCP can be justified for hydrometric operations really is the lifetime (with repairs) of a DCP.

In 1978, the demonstrated lifetime of a Water Survey of Canada DCP is 6 years. All units installed in 1972 continue to operate - some without any repairs to date. It has not been necessary to write-off any due to massive electronic failures, or loss due to floods or vandalism.

Although this analysis relates mainly to the Water Survey of Canada's remote access gauging stations, there is another large group of stations where telemetry may prove economically feasible. This is the network of some 500 tide gauging and in-land lake stations where only water level data are collected. Only a few of these are remote access, but since there is no requirement to visit the stations to obtain discharge measurements, the number of visits to a station could be reduced from ten or twelve each year to two or three if memory equipped DCPs were used as the primary data collection tool.

If this change were made, the only reason to visit a water level station would be to ensure that there were no shifts in gauge datum and that sensors were operating normally. Savings in field travel costs and the elimination of the necessity to hire paid local observers could reduce annual operating costs by about \$1,000. The capital cost of a DCP and water level encoder could therefore be recovered in about six years.

Given these favorable cost benefit figures, why has deployment of DCPs in Canada proceeded at a relatively slow pace? The principal reason has been the lack of an operational satellite system that meets all requirements. While the service provided by Landsat is excellent, the system is experimental and therefore cannot be used as the basis for any long term project. The operational GOES system often cannot be used in mountainous or high latitude areas because of antenna aiming problems. Studies have been made of Canadian satellite systems that could be used for data collection but these could not be operational until sometime in the 1930s.

It now seems likely that the Water Survey of Canada will select GOES self-timed DCPs at all sites where it is technically feasible and will use the TIROS-N Argos system where GOES is not feasible. This assumes of course, that the Argos system meets published specifications.

Another factor that slows the deployment of DCPs is that it is necessary to spend capital funds in one year to save operational funds over a number of years. This would require restructuring of the Water Survey of Canada budget if large scale deployment of DCPs were to take place. Also the time at which use of DCPs for hydrometric operations becomes economic has been just about the demonstrated lifetime of a DCP. Indications now are that DCPs will last a sufficiently long period of time to make this factor less important.

The future of satellite telemetry in Canada now looks very good and more large scale deployment of DCPs can be expected in the not too distant future. A contract for development of a TIROS-N (Argos)/GOES DCP has recently been awarded to a Canadian company.

V. PUBLICATIONS

- Jan. 13-15, 1975 "Sensor Data Retransmission by Satellite" paper by R.A. Halliday, presented at the Canadian Remote Sensing Society Workshop on Remote Sensing of Snow Cover, Ottawa, Ontario.
- Aug. 7, 1975 "Satellite Data System Expanded", news release by Stephen Rybak, Inland Waters Information, Dept. of the Environment, to the Canadian wire service.
- Sept. 8-13, 1975 "Data Retransmission by Satellite for Operational Purposes" paper by R.A. Halliday was prepared for presentation at the International Seminar on Modern Development in Hydrometry, Padua, Italy.
- Oct. 6-10, 1975 "Some Operational Uses of Satellite Retransmission in Canada", invited paper by R.A. Halliday and I.A. Reid for presentation at Tenth International Symposium on Remote Sensing of Environment, Ann Arbor, Michigan, U.S.A.
- November, 1975 "Use of Satellites in Data Retransmission" invited paper by R.A. Halliday for World Meteorological Organization (WMO) Casebook on Hydrological Network Design Practice.
- June 16, 1976 "Preliminary Results Using GOES Data Collection System" paper by I.A. Reid, A.C.D. Terroux and R.A. Halliday for Data Collection System Users Conference, Washington, D.C.

- July 15-16, 1976 "Hydrometric Field Procedures - Water Survey of Canada" paper by R.A. Halliday for World Meteorological Organization, International Seminar on Organization and Operation of Hydrologic Services, Ottawa, Canada.
- Oct. 19, 1976 "Retransmission of Hydrometric Data in Canada", an oral report to the NASA water resources panel by R.A. Halliday. (notes are available)
- Dec. 16, 1976 "Equipment Development and Automation - Hydrometric Field Work", paper by R.A. Halliday and E.F. Chapman for the First Annual Meeting of the Water Survey of Canada, Pacific Region. (Contains some information on satellite DCS - text is available.)
- Dec., 1976 "Discrete Sampling of Hydrologic Data", paper by G.W. Kite and I.A. Reid.
- Oct.-Dec., 1976 "Satellites Help the North" article by I.A. Reid for the Arctic Circular (distribution list of approximately 1000).
- March 18, 1977 "Hydrologic Data Relay by Satellite from Remote Areas", invited paper by R.A. Halliday for the Technical and Scientific Sessions on Water Resources, World Water Conference, Mar del Plata, Argentina.
- April 22, 1977 "Hydrologic Applications of the TIROS-N Argos Data Collection System", paper by R.A. Halliday and I.A. Reid, for the first Argos users working group meeting, Washington, D.C.

- May 26, 1977 "Present and Future Needs for Retransmitting Hydrometric Data Via Satellite in Canada", paper by I.A. Reid, for Seminar on Present Day and Future Transfer Systems for Water Resource Data Collection and Dissemination.
- November, 1977 "A Solar Electric Power Design for Charging a Battery System", report by J.A. Long for Water Survey of Canada, Winnipeg. (A Landsat DCP was used to monitor the performance of solar power systems - text is available.)
- April, 1978 "A Plan for the Collection and Transmission of Hydrometeorological Data in the Brazilian Amazon Basin", report by Robert Halliday, for the World Meteorological Organization.
- 1978 "The Use of Satellites in Hydrometry" by Robert A. Halliday, Chapter 12 in Hydrometry: Principles and Practices, R.W. Herschy, editor, John Wiley publisher.

VI. PROBLEMS

Two major problems impeded progress on the project. These were problems relating to the Ball DCPs that were purchased in 1974 and problems in implementing the receive site at PASS.

On December 18, 1973 a contract for 19 convertible Landsat/GOES DCPs (Model CDCP-100) at a price of US \$4,500 each was let to Ball Brothers Research Corporation. Delivery was scheduled for completion by June 30, 1974. An order for one DCP memory for connection to a GE DCP was also placed at about the same time.

This memory was eventually installed in one of the Ball DCPs.

Because of delays in the DCP contract, no deliveries took place until 1975 and the first DCPs were not installed in the field until July 1975. One problem that was discovered as soon as the DCPs were delivered was that the manufacturer had specified the mating connectors incorrectly therefore it was necessary to reorder all connectors. This problem could have been eliminated if the DCP contract had stated that the manufacturer supply all mating connectors (as was the case when the GE DCPs were purchased).

One design fault was also noted on delivery, namely that there was no logic ground on one of the connectors, therefore it was necessary to run internal or external jumpers to provide this ground. A much more serious design problem was that none of the DCPs would operate in the GOES mode. This problem was eventually resolved early in 1976. It was necessary to make changes in both the central processing and the frequency generator modules before the platforms would operate in the GOES mode.

Several manufacturing defects were noted in the Ball DCPs. The most common defect was an improperly terminated 2nd harmonic trap. In one DCP (6501) there was a fault in the program connectors causing the DCP to transmit 0000 as an ID. One DCP (6504) had a temperature related intermittent fault in the Landsat mode and would operate only in above freezing temperatures. This problem was never resolved and eventually the DCP was converted to GOES operation. Two DCPs were returned to Ball for repairs; all other repairs were performed by electronics personnel from the Department's Glaciology Division.

In retrospect, the main difficulty with the Ball DCPs was that the company went out of the DCP business shortly after their

initial production run was completed. The DCP operation was handled by another division within the company for a while but it was very difficult to obtain any after sales service or advice. The moral of the story would be for users to deal only with companies that are in the DCP business to stay.

It should be noted however, in fairness to Ball, that none of their DCPs have failed in use in Canada once transmissions have been successfully started. The platform did pave the way for other convertible DCPs.

During the reporting period the following failures occurred to the GE DCPs:

DCP 6137 would not transmit. It was found that the zinc coating on the transmitter boards heat sink had flaked off thus shorting the transmitter. The heat sink was cleaned up then anodized and the DCP re-installed.

DCP 6354 would not transmit. The fault was traced to IC U38 on the A3 Assembly, Programmer Board. The IC was replaced.

DCP 6260 would not transmit in the 180 s mode. The IC labelled U3 in figure 5-4 of the GE manual was found to be defective.

DCP 6126 would not transmit. The fault was traced to defective power transistors on the output stage, Transmitter Board.

Data from DCP 6354 not received. The fault was traced to IC U18 on the Programmer Board. This failure inhibited insertion of the preamble and address in the message.

On August 16, 1976 a contract for \$160,000 was awarded to

SED Systems for design, development, fabrication, installation and debugging of a Landsat/GOES data collection system receive site at PASS. Delivery of the system was scheduled for May, 1977 but in actual fact it wasn't until October of 1977 that the Landsat system became useable on teletype and February, 1978 that the Telex system was in operation. The GOES system is still not operational.*

In the Landsat case the problem was in the enable circuitry of the bit synchronizer that was supplied by Aydin Monitor Systems. The circuitry was eventually modified by Aydin at SED's expense. It took from mid-May to September before this problem was resolved. (Late delivery of components was also a problem.) SED suspects that the problem with GOES operation is also in the Aydin equipment; this should be resolved by May 1978.

Diagnosis of these problems would have been much simpler if the terms of the contract with SED had permitted them to buy simulators to generate Landsat and GOES type messages. This would have eliminated dependence on receiving actual DCP messages at PASS for diagnostic purposes. Personnel at PASS have now constructed a Landsat simulator.

It is also apparent that the after sales service provided by Aydin Monitor Systems leaves something to be desired.

VII. DATA QUALITY AND DELIVERY

A check of the message quality of a 50 day period of Landsat DCS data received from NASA showed the following results:

Message quality:	0	1	2	3	4	5	6	7
No. of Messages:	103	4	9	18	16	43	96	14 767

* The first GOES messages were received at PASS in late July, 1978.

The total number of messages received was 16 056 with 98% being quality 7.

The decoding routine used at PASS seems to flag a higher percentage of messages received as being less than quality 7, however no errors have been noted in data flagged as quality 5 or 6.

Examination of a random sample of one week's messages revealed that it takes from a few minutes to several hours from the time the messages are transmitted by a DCP to the time the messages are received by dedicated phone line at the Canada Centre for Remote Sensing, Ottawa. Except for possible emergency situations this time delay does not degrade the usefulness of Landsat data. The hard copy in card form arrives 10 to 14 days after the messages have been transmitted. Again, this time delay does not degrade the usefulness of the system. The messages received at PASS are available for dialup within seconds of their receipt.

VIII. RECOMMENDATIONS

As it has now been demonstrated that satellites can be used to relay water resources data from remote sites economically on a quasi-operational basis, the purpose of this investigation has been met. The main effort on the part of the Water Survey of Canada should be devoted to implementing a completely operational system. This could be accomplished over a period of about 18 months by converting all existing Landsat/GOES convertible DCPs to GOES operation, purchasing TIROS-N Argos DCPs for sites where use of GOES is not feasible and installing a TIROS-N receive site in Canada.

However, it would be useful to continue operations with

the ten GE Landsat DCPs for as long as Landsat DCS is available just to determine the useful life of a DCP. If Landsat-3 lasts as long as Landsat-1, this would mean continuing the experiment through to 1984 or until all DCPs are unserviceable - whichever comes first.

In any event, the program should be continued until TIROS-N Argos service is fully established as there are sites in Canada where geostationary satellites cannot be used.

IX. CONCLUSIONS

The deployment of about 30 DCPs during the Landsat-2 program has demonstrated that near real time data can be collected reliably and effectively using polar orbiting satellites. Such data can be used for many operational purposes. Of particular interest to the Water Survey of Canada is the fact that satellite data collection tends to reduce gauging station operating costs.

It seems economically feasible to operate DCPs at many gauging stations in Canada. The main task is to select a system that meets all operational requirements. A combination of the GOES and Tiros N could come close to meeting user needs.

X. ACKNOWLEDGEMENT

The authors wish to acknowledge the contributions of R.O. Christie and T. Maxim, Instrumentation Section, Glaciology Division in trouble shooting and repairing DCPs, R.K. Aylesworth, Data Control Section, Applied Hydrology Division in preparing programs for processing Landsat output cards, H. Edel, Canada Centre for Remote Sensing, in developing the real time data distribution system at CCRS, and K. Sander, a student assistant who assembled much of the material contained in this report.

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